I. C. 7098 FEBRUARY 1940

UNITED STATES
DEPARTMENT OF THE INTERIOR
HAROLD L. ICKES, SECRETARY

BUREAU OF MINES
JOHN W. FINCH, DIRECTOR

INFORMATION CIRCULAR

COOLING MINE AIR DURING SUMMER MONTHS TO PREVENT ROOF FALLS

RECEIVED
MAR 30 1940
O. S. U. LIBRARY

BY

C. A. HERBERT

AFTER THIS REPORT HAS SERVED YOUR PURPOSE AND IF YOU HAVE NO FURTHER NEED FOR IT, PLEASE RETURN IT TO THE BUREAU OF MINES, USING THE OFFICIAL MAILING LABEL ON THE INSIDE OF THE BACK COVER.

Generated on 2024-09-19 08:03 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

I. C. 7098,
February 1940.

INFORMATION CIRCULAR

UNITED STATES DEPARTMENT OF THE INTERIOR - BUREAU OF MINES

COOLING MINE AIR DURING SUMMER MONTHS TO PREVENT ROOF FALLS[1]

By C. A. Herbert[2]

In summer, when hot, moisture-laden air enters a coal mine in the region east of the Mississippi River, the moisture is likely to condense on the roof and ribs because the incoming air is cooled below its dew point upon contact with the roof, ribs, and floor of the mine passageways. When the roof and ribs become wet owing to this condensation they are said to "sweat." In many mines, as soon as this sweating begins, shale or slate roof that appears solid and strong in winter begins to cut and fall. For a long time most mining men believed (many still believe) that the roof trouble was due to this sweating. However, from observation of conditions in one mine the operators concluded that the trouble was caused by expansion and contraction of the roof due to changes of temperature. This opinion was confirmed by experiments at several mines in cooling the air as it entered the mines. Methods used in these mines for cooling the air are described in this circular.

MINE A

At mine A the roof gave considerable trouble in the summer, and it was observed that where a spray of water from a leaking dam kept the roof wet and at a uniform temperature no difficulty was experienced with the roof, although it had cut and fallen on either side of that point. From this fact the company officials concluded that changes of temperature in the air rather than moisture caused the trouble and that if the incoming air were cooled to approximately normal strata temperature much of the additional roof trouble experienced during the summer would be overcome.

To this end an air washer or cooler was installed in 1927 on the surface in an extension of the intake air drifts of the fan (see fig. 1) and has been operated continuously during the summers since then. The results are said to have been very satisfactory.

The air-cooling unit at this mine is essentially an air washer of standard design using four banks of spray nozzles, of which two normally are for cold water and two for recirculated water. The cooling unit operates automatically by thermostatic controls. As soon as the air

1/ The Bureau of Mines will welcome reprinting of this paper provided the following footnote acknowledgment is used: "Reprinted from Bureau of Mines Information Circular 7098."

2/ Supervising engineer, Bureau of Mines Safety Station, Vincennes, Ind.

Generated on 2024-09-19 06:53 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

entering the unit reaches a temperature above that desired a valve between the cold-water line and the cold-water sprays opens, and the recirculating pump starts. As the temperature increases the cold-water valve opens still wider until the full capacity of the cold-water sprays is reached. If the temperature of the air leaving the cooling unit exceeds the desired temperature when the cold-water sprays are running at full capacity a valve between the cold-water line and the recirculating sprays opens automatically and admits cold water to these sprays. This cold water circulates because it is under a pressure of 60 pounds per square inch, whereas the recirculating water is under a pressure of only 30 pounds per square inch.

By this arrangement fewer spray nozzles take care of peak temperature and humidity conditions than would be required if the outer two banks of sprays were used for recirculated water only. At the same time the efficiency of the unit in transferring heat is materially reduced during these peak periods, and more cooling water is required.

Just inby the cold-water sprays are zigzag baffle plates to remove entrained moisture from the air before it enters the fan. These baffles have a resistance to the passage of air equivalent to about one-half inch of water-gage pressure. Approximately 50,000 cubic feet of air is circulated per minute at this mine.

Water is obtained at a temperature of 56° F. from a well sunk to a water-bearing gravel bed in the river bottom.

MINE B

This mine is operated on a room-and-pillar system in a relatively flat coal bed at a depth of about 110 feet. The roof is a soft shale which is particularly hard to hold in summer when the roof begins to sweat. An air-cooling unit was installed in the intake air course near the bottom of the air shaft and has proved effective in eliminating roof troubles. The air cooler was installed underground because the supply of cooling water comes from abandoned mine workings.

There is a sheet deposit of water-bearing gravel in the drift material immediately above the roof strata; when rooms cave, as they frequently do owing to the soft shale roof, the caves extend up to this gravel causing inrushes of great quantities of water.

To solve this problem and avoid pumping large volumes of water the mine is developed on a panel system. A panel comprises a pair of room entries with rooms turned off each entry. Each panel is surrounded by a pillar of coal that separates it from adjoining workings, therefore, the only openings into these panels are the two room entries. As soon as the coal is extracted from the panel, concrete dams or bulk-heads are built in the mouths of the two entries.

Generated on 2024-09-19 06:47 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

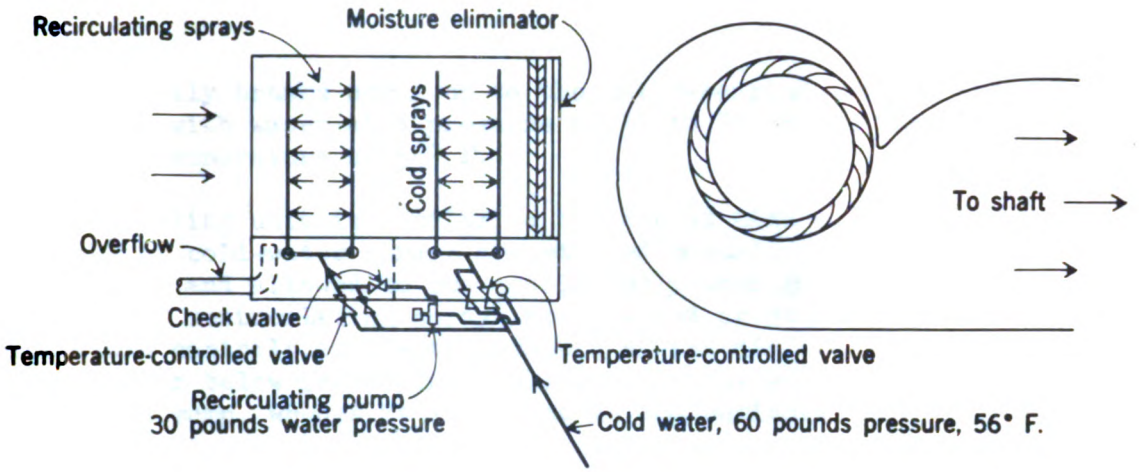

Figure 1.—Arrangement of air cooler, mine A.

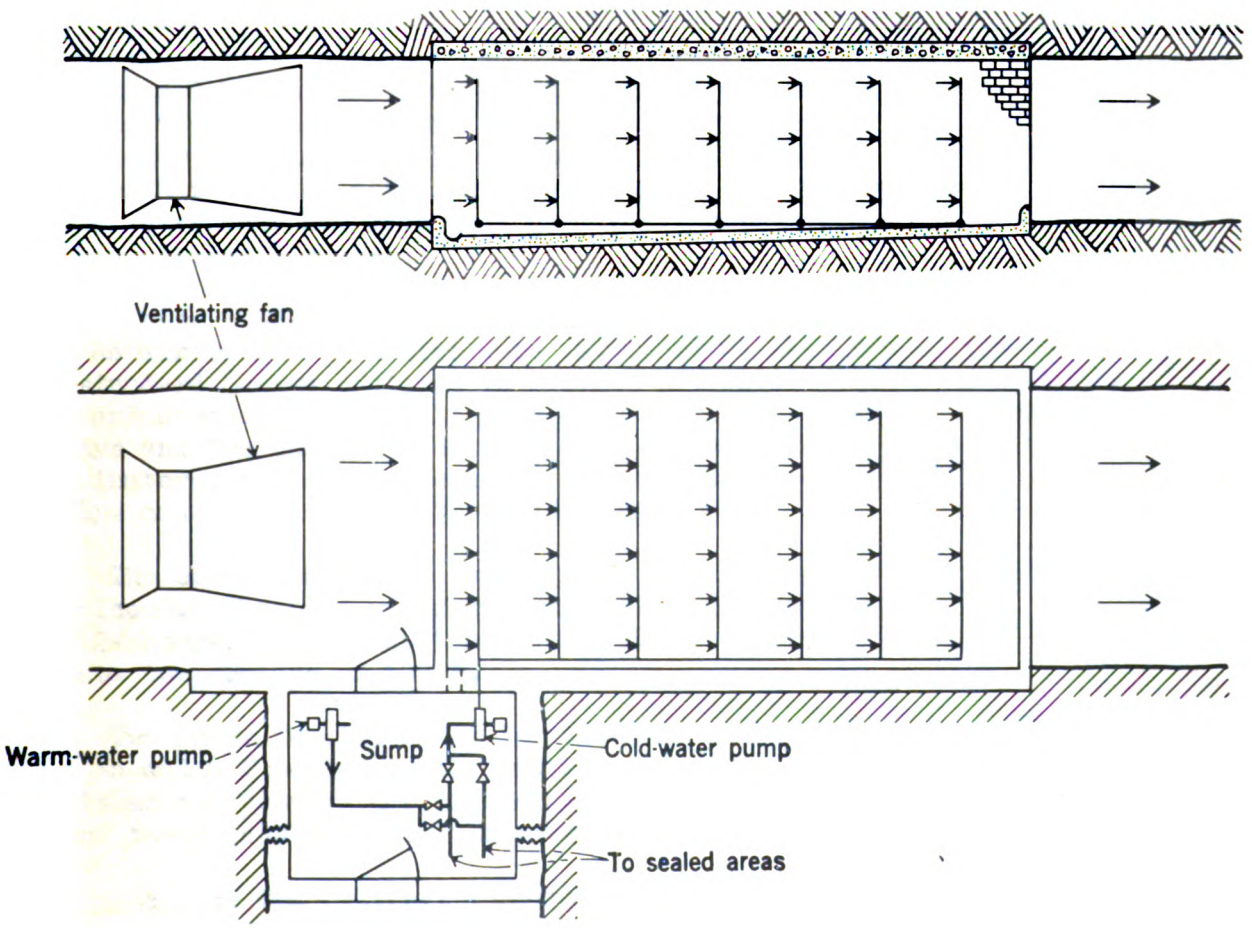

Figure 2.—Diagram of air-cooling unit, mine D.

Generated on 2024-09-19 08:11 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from
THE OHIO STATE UNIVERSITY

Eventually breaks occur up to the water-bearing gravel, and the panels fill with water at a pressure of 30 to 35 pounds per square inch and a temperature of 55° F.

The cooling unit is similar to the one at mine A, except that the two banks of cold-water sprays are started manually at the beginning of warm weather and allowed to run continuously throughout the summer. The two banks of recirculating sprays are started or stopped by automatic temperature controls as the temperature of the air leaving the cooler goes above or below predetermined levels. Waste water from the cooler drains to a sump, whence it is pumped to the surface.

Zigzag baffle plates are installed just inby the cold-water sprays to remove entrained moisture.

Approximately 25,000 cubic feet of air is circulated per minute at this mine.

MINE C

Mine C has a shale roof that requires constant attention and is difficult to hold, even with close and careful timbering. Before an air cooler was installed it was so difficult to hold the roof in the summer that safe or efficient operation of the mine was almost impossible, and on extremely hot days roof conditions became so bad that it is said to have "rained" slate.

During 1935, in connection with a modernization program, a new fan and an air washer or cooler were installed at this mine. The cooler is of standard design enclosed in a steel casing and placed between the fan and downcast shaft. It is equipped with two banks of cold-water sprays and two banks of recirculating sprays and has two sets of moisture eliminators, one set between the recirculating sprays and the cold-water sprays and one just inby the cold-water sprays.

The operation of the cooling unit is similar to that of the unit at mine B. The cold-water sprays are run continuously at full capacity for 24 hours, unless the temperature drops considerably below the normal strata temperature of 60° F.

Two pumps furnish water for the recirculating sprays. They are cut on and off automatically one at a time by separate temperature controls as the temperature of the air leaving the cooler goes above or below the points at which the controls are set.

The mine fan delivers approximately 60,000 cubic feet of air per minute against a water-gage pressure of 1 1/2 inches. A pressure of one-half inch (one-third of the ventilating pressure) is required to overcome the frictional resistance of the cooling unit.

Generated on 2024-09-19 06:47 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The mine operates in two coal beds on separate shifts; however, all coal is hoisted from the same shaft and prepared near it. As most of the output is washed, large quantities of water are required during the two working shifts. In summer while the cooling unit is in operation the water for the washery is first run through the cooler. Any surplus above the washery requirements is run to waste.

Water is obtained from a gravel bed in the river bottom and reaches the mine at a temperature of 57 1/2° F.

MINE D

At this mine cold water is not available on the surface for use in a cooling unit; however, a considerable sealed area of old underground workings is nearly full of water. This water is alkaline because exclusion of air from these areas by the tight seals prevents the formation of sulfuric acid due to oxidation of the iron pyrite in the coal.3/ However, the water is high in mineral salts.

Because of the trouble experienced with the roof in summer and the successful use of coolers at other mines in this field it was decided to install an air washer or cooler underground at this mine and to employ the water impounded behind the seals.

The combined area of two sealed regions containing water a short distance from the cooler that contains water is approximately 250 acres. It was thought that by pumping the water from one sealed area through the sprays into the other, then reversing the process, the water pumped back would dissipate its heat to the surrounding strata rapidly enough to allow its reuse.

The temperature of the water at the beginning of the summer is approximately 56° F., but by the time the cooler is shut down at the end of summer the temperature of the water has increased to about 60° F.

Although the water is alkaline and noncorrosive it is highly mineralized, and continual aeration of the water through the sprays causes a brown precipitate to form (probably a hydrous oxide of iron), which adheres to the pipes and so obstructs the flow of water that it is necessary to re-lay the pipe at intervals.

The cooling unit was installed on the main intake air course a short distance from the foot of the downcast air shaft and just inby the ventilating fan, which is underground. The fan delivers approximately 65,000 cubic feet of air per minute.

3/ Leitch, R. D., Yant, W. P., and Sayers, R. R., Effect of Sealing on Acidity of Mine Drainage: Bureau of Mines Rept. of Investigations 2994, 1930, 11 pp.

Generated on 2024-09-19 06:47 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

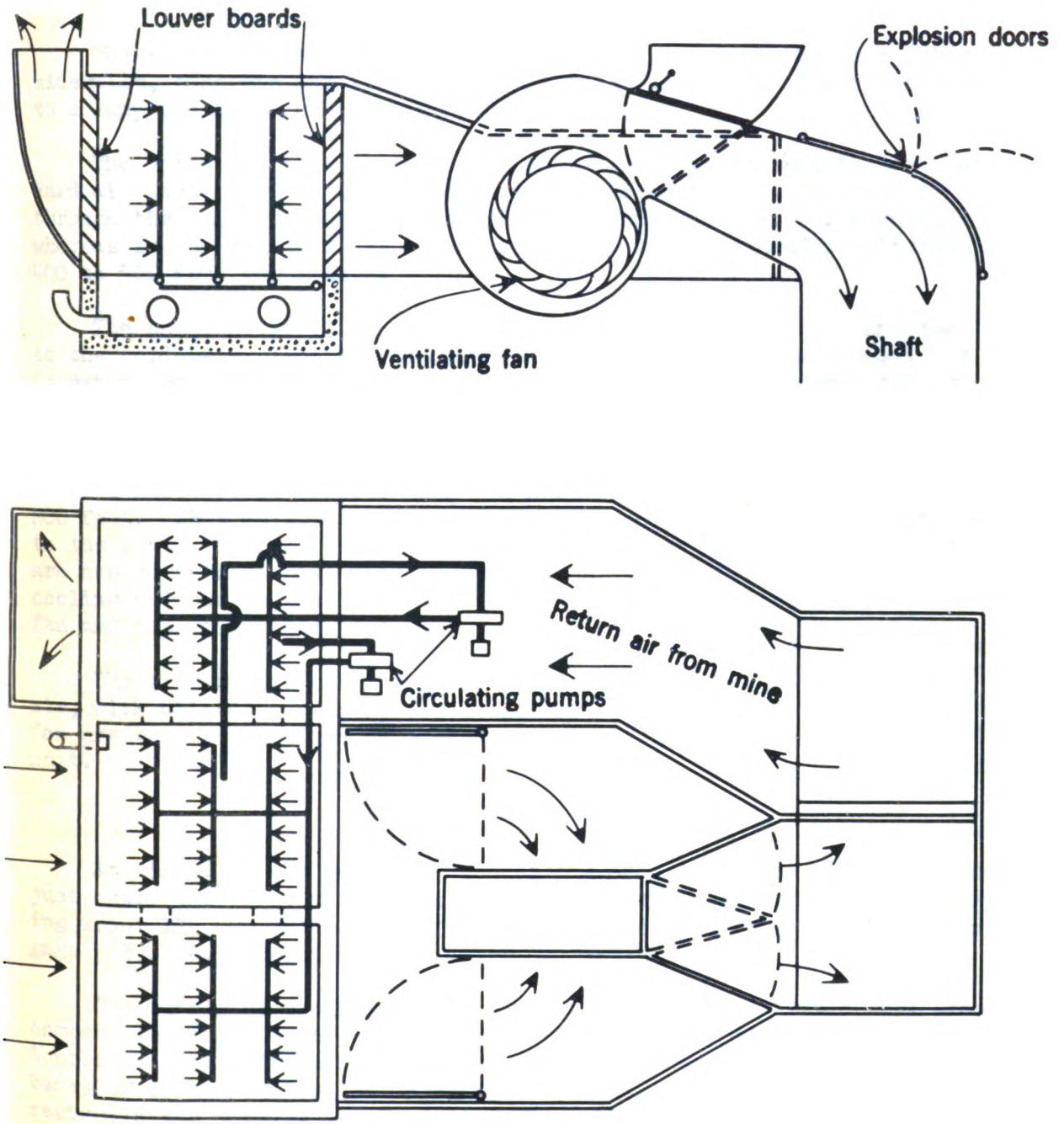

Figure 3.— Diagram of cooling unit, mine E.

Generated on 2024-09-19 06:46 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

This unit is a departure from the standard air washers at the other mines. It comprises seven banks of sprays set 3 1/2 feet apart. Each bank has 18 spray nozzles, making a total of 126.

The section of the air course forming the spray chamber has brick sidewalls, concrete and steel roof, and concrete floor. The floor slopes to a sump under the circulating pumps. (See fig. 2.)

The sprays in this installation are farther apart than in the standard air washer. This is probably an advantage, as the air velocity through the spray chamber is slightly more than 800 feet per minute, whereas in the standard air washer or cooler the recommended velocity is 400 to 500 feet per minute.

The cooling water is not recirculated. All sprays are connected to the cold-water line and are run continuously during the summer. It is estimated that approximately 600 gallons of water is circulated per minute through the sprays.

Moisture eliminators were not installed in this unit, and some entrained moisture is carried with the air and precipitated largely within 200 feet. This moisture offers essentially no problem, as it drains back to the sump. In fact, it is questionable whether moisture eliminators are needed in most coal-mine installations, except perhaps where the cooling unit is on the inlet side of the fan and might corrode when the fan and fan casing are kept wet.

The eliminators offer considerable resistance to the passage of air, with attendant consumption of power. In mine C one-third of the fan pressure is required to overcome the resistance offered by the cooling unit.

MINE E

At mine E an air washer or cooler has been installed on the surface just outby the inlet air drifts of a double-inlet centrifugal fan delivering about 125,000 cubic feet of air per minute against a 2.7-inch water-gage pressure. (See fig. 3.)

The supply of cooling water is so limited that it little more than compensates the loss by evaporation. Therefore, in addition to the double cooling unit in front of the fan drifts, each of which has three banks of spray nozzles, an adjoining third unit (with three banks of recirculating sprays) was installed through which part of the cool return mine air is drawn. As the spray tanks of all three sets of sprays are connected and as the return-air temperature is between 60° and 65° F. it was thought that this third recirculating unit might help to reduce the temperature of the water in the spray tanks.

Generated on 2024-09-19 07:59 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

The return air of most coal mines is nearly saturated, so there can be little or no evaporative cooling in the third unit. Any cooling of the tank water will take place largely by convection.

Although it is claimed that cooling the air at this mine has lessened roof falls, the air leaving the cooler and entering the mine is only 2° or 3° lower than the wet-bulb temperature of the outside air and varies with the wet-bulb temperature.

General Discussion

It is the practice in the midwestern coal fields to operate the mine ventilating fans blowing, with the hoisting shaft and the main haulage roads on the return air course. It will be noted that the installations of air washers or coolers that have been described are at mines where the fans are so operated.

It would be much safer if the fans were run exhausting and the hoisting shaft and main haulage roads were on the intake air course; however, the ideal arrangement in installing an air washer or cooler is to have the fan run blowing, as the cooling unit can be placed on the surface, either on the intake or discharge side of the fan, or on the bottom of the main intake air course. The choice of location, whether on the surface or underground, is determined largely by the source of the cooling water.

At a shaft mine having only two shafts, where the hoisting shaft and main haulage roads are on the intake air course, obviously it would be impossible to install the air washer or cooler on the surface, and if they were installed underground the cooling unit would have to be placed in an entry parallel to the haulage entry. This would necessitate an air lock on the haulage road long enough for the passage of empty and loaded trips. The doors forming the air lock should be automatic so as not to interfere greatly with haulage operations. (See fig. 4.)

In a slope or drift mine, where the main slope or drift is on the intake air course, it might be possible to install the cooling unit in a separate opening, but an air lock would have to be placed on the haulage road outby the intake connection in which the cooler is installed. (See fig. 5.)

PRACTICABILITY OF COOLING AIR ENTERING MINES IN SUMMER

Whether or not it is practical to cool the air entering a mine in the summer will depend first on an ample supply of cold water and the situation of this water with reference to the place where the air-cooling units are to be installed. At a deep mine, where the cooling unit must be underground and the supply of cooling water is above ground, doubtless

Generated on 2024-09-19 06:47 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-19 06:47 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

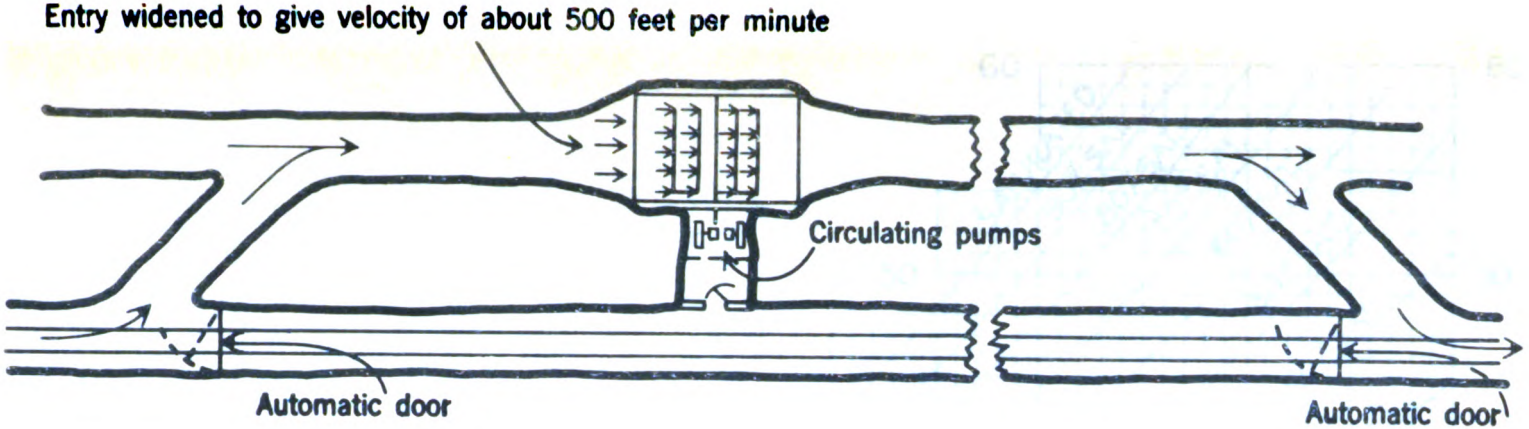

Figure 4.—Underground cooling unit when hoisting shaft and haulage road are on the intake air course.

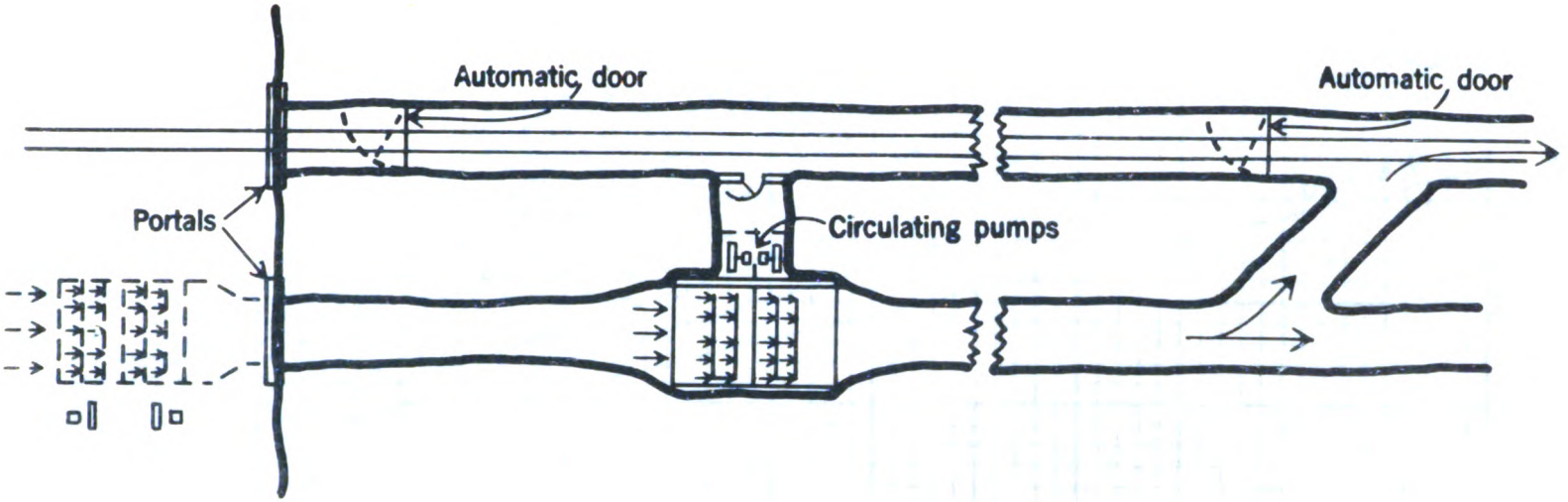

Figure 5.—Cooling unit installed underground or on surface at a drift mine with haulage on intake air course.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-19 06:46 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

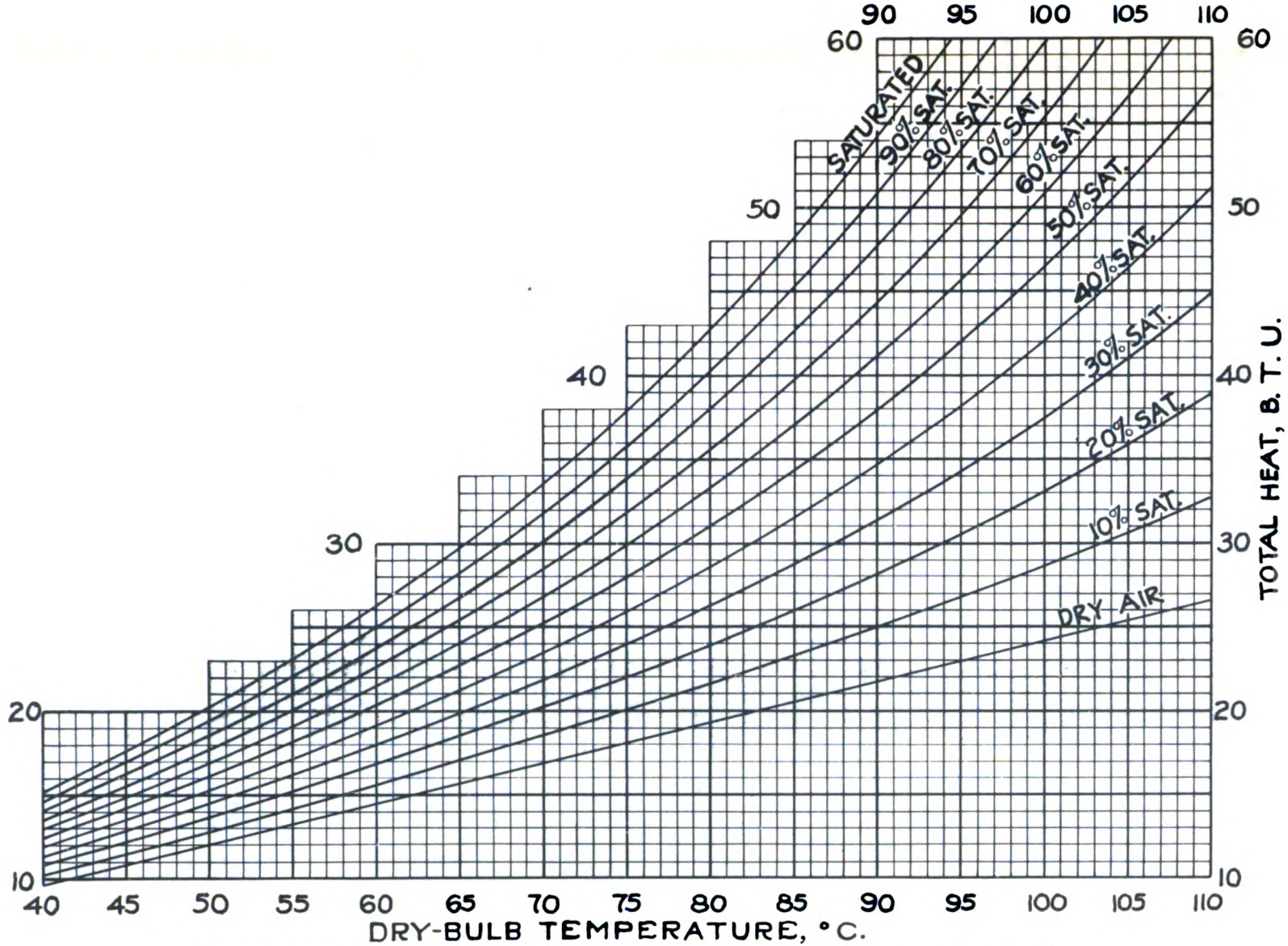

Figure 6.—Total heat in 1 pound of dry air plus moisture in varying degrees of saturation; barometric pressure, 29.92 inches mercury.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

the pumping costs would be too great to warrant such an installation. On the other hand, if there is a usable supply of water underground that must be pumped out of the mine, the water could be utilized first for air cooling at little additional cost.

In other words, the practicability of air cooling coal mines with water sprays is more or less an individual problem at each mine, and it would be advisable for mine operators to consult the manufacturers of air washers before attempting to install an air-cooling unit. Equipment of this type has been used in connection with air conditioning buildings for years, and manufacturers are in a position to guarantee the performance of their cooling units.

In cooling mine air by air washers or water-spray cooling units similar to the installations described in this report there is merely an exchange of heat and moisture between the air passing through the cooler and the spray water. Obviously, therefore, the amount of heat taken up by the water is equal to the difference between the total heat in the air entering the cooler and the total heat in the air leaving the cooler and passing into the mine.

For practical purposes the total heat in air may be considered as the sensible heat in the dry air plus the latent heat in its water-vapor content. Therefore the total heat in air varies not only with the temperature of the air but also with its moisture or relative humidity. On days when the temperature is extremely high the relative humidity usually is comparatively low. As a result, the total heat in the air often is not as great on such days as on days when temperatures are lower and humidities higher.

The heat curves shown in figure 6 were prepared from the data given in table 1. The data for the curves showing 10, 20, 30 percent saturation, etc., were obtained by adding the heat above 0° F. of 1 pound of dry air (for the various temperatures shown in column 5) to 10, 20, 30 percent, etc., of the latent heat of vapor necessary to saturate 1 pound of dry air at the corresponding temperatures shown in column 6.

Temperature and Humidity in Mine Air

To obtain some idea of the amount of heat in the air in various localities throughout the coal fields, in which it might be advantageous to cool the mine air during the summer, July and August Weather Bureau records for 10 years were studied at Birmingham, Ala., Pittsburgh, Pa., Evansville, Ind., Springfield, Ill., and Oklahoma City, Okla.

From the temperature and relative-humidity data in these records and the curves in figure 6, the maximum total heat (sensible plus latent) in 1 pound of dry air plus the water-vapor content at noon was calculated by months for the 10 years.

Generated on 2024-09-19 06:54 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Generated on 2024-09-19 08:02 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google

TABLE 1. - Weight, volume, and heat in 1 pound of dry air above 0° F., heat in saturated aqueous vapor, and total heat in 1 pound of dry air plus vapor to saturate 1/

Temperature, °F.	Volume of 1 pound of dry air, cubic feet	Volume of saturated vapor in 1 pound of dry air, cubic feet	Volume of 1 pound of dry air plus vapor to saturate (columns 1 and 2)	Weight of saturated vapor in 1 pound of dry air, pound	Sensible heat of 1 pound of dry air above 0°F., B.t.u.	Latent heat of vapor in 1 pound of dry air plus vapor to saturate, B.t.u.	Total heat above 0° F. of 1 pound of dry air plus vapor to saturate, B.t.u.	Temperature, °F.
0	11.58	0.01	11.59	0.000781	0.00	0.96	0.96	0
10	11.83	.03	11.86	.001309	2.41	1.61	4.02	10
20	12.09	.04	12.13	.002144	4.82	2.62	7.45	20
32	12.39	.08	12.47	.003782	7.72	4.06	11.77	32
35	12.47	.08	12.55	.004268	8.44	4.57	13.01	35
40	12.59	.11	12.70	.005202	9.65	5.56	15.21	40
45	12.72	.13	12.85	.00632	10.86	6.73	17.59	45
50	12.84	.16	13.00	.00764	12.07	8.12	20.19	50
55	12.97	.19	13.16	.00920	13.28	9.76	23.04	55
60	13.10	.23	13.33	.01105	14.48	11.69	26.17	60
65	13.22	.28	13.50	.01323	15.69	13.96	29.65	65
70	13.35	.34	13.69	.01578	16.90	16.61	33.51	70
75	13.48	.40	13.88	.01877	18.11	19.71	37.82	75
80	13.60	.49	14.09	.02226	19.32	23.31	42.63	80
85	13.73	.58	14.31	.02634	20.53	27.51	48.04	85
90	13.86	.69	14.55	.03109	21.74	32.39	54.13	90
95	13.98	.82	14.80	.03662	22.95	38.06	61.01	95
100	14.11	.97	15.08	.04305	24.16	44.63	68.79	100
105	14.24	1.15	15.39	.0505	25.37	52.26	77.63	105
110	14.36	1.37	15.73	.0593	26.58	61.11	87.69	110

1/ Taken from Goodenough's tables.

Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Observations on the temperature and relative humidity at Weather Bureau stations are made three times a day - in the morning, at noon, and in the evening. The three daily readings were averaged for the entire 10-year period. With the aid of figure 6 the average daily total heat for these three observations was calculated. Table 2 gives these data, the maximum total heat at noon for the 10 years, and the average of the monthly maximum total heat.

A regular psychrometric chart might have been used to calculate the total heat from the Weather Bureau data, but it is believed that the curves in figure 6 are easier to read for total heat only.

If the wet-bulb readings had been given in the Weather Bureau records, only the upper curve for saturated vapor would have been necessary, as the total heat in the air is a function of the wet-bulb temperature only (for constant pressure) and is a constant for any wet-bulb reading, irrespective of the dry-bulb reading.

At all these places (except Pittsburgh, Pa.) where the Weather Bureau records were studied, there were many days during the 10-year period when the dry-bulb temperature at noon was well over 100° F., but the relative humidity on those days was comparatively low, so that the total heat in the air was not excessive.

The maximum daily dry-bulb temperature is seldom reached by noon, so doubtless the figures for maximum total heat in table 2 are slightly low; however, the periods of maximum total heat are of short duration, lasting only an hour or two, so the figures given are believed to be high enough to use as a basis for designing equipment. In fact, it is thought that a cooling unit capable of taking care of the average of the monthly maximum total heat would be satisfactory. It is doubtful if a raise in temperature of a few degrees in the air entering the mine for only an hour or two would have any appreciable ill effect on the roof, especially as these periods of excessive total heat are infrequent.

The normal temperature of inside mine air throughout the central coal fields is approximately 60° F. This temperature varies somewhat in different mines in the same field. In other fields, the mine-air temperature may vary considerably from that in the central fields. For example, the mine-air temperature of some coal mines in the McAlester (Okla.) field is above 70° F.

Amount of Water Required to Cool Mine Air

The amount of cooling water that will be required to cool the air entering the mine depends on the following factors:

1. The temperature of the cooling water available.

2. The maximum total heat in the outside air during the hot summer months.

Generated on 2024-09-19 08:02 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

TABLE 2. - Average daily total heat, maximum total heat at noon for 10 years, and average of monthly maximum total heat

	Birmingham, Ala., July and August for 10 years	Pittsburgh, Pa., July and August for 7 years	Evansville, Ind., July and August for 10 years	Springfield, Ill., July and August for 10 years	Oklahoma City, Okla., July and August for 10 years
Noon					
Maximum total heat above 0°F. (sensible and latent) in 1 pound of dry air plus water vapor.....B.t.u...	43.3	40.1	44.1	43.3	42.1
Noon					
Wet-bulb reading.....°F. .	80.6	77.2	81.3	80.5	79.2
Dry-bulb reading.....do. .	88	87	94	92	90
Relative humidity.....percent..	73	65	58	61	63
Noon					
Average of monthly maximum.....B.t.u. .	40.8	37.1	41.7	40.8	40.0
Average wet bulb.....°F. .	78.6	74.4	78.6	78.2	76.8
Average dry bulb.....do. .	90.3	85.5	91.7	92.2	93.9
Average relative humidity.....percent..	59	60.4	56.5	54.2	47.2
7 a.m. 1/					
Average daily total heat.....B.t.u. .	34.0	28.3		30.2	32.5
Average daily wet bulb.....°F..	70.2	63.2		65.4	68.0
Average daily dry bulb.....do..	73.8	68.4		70.7	73.3
Average daily relative humidity..percent..	84.5	76.8		76.1	76.7
Noon					
Average daily total heat.....B.t.u. .	37.5	29.8	34.3	33.8	36.2
Average daily wet bulb.....°F. .	75.0	65.2	71.1	70.0	73.3
Average daily dry bulb.....do. .	86.6	77	84	83.6	89.1
Average daily relative humidity..percent..	56.9	53	53.2	51.2	47.4
7 p.m. 1/					
Average daily total heat.....B.t.u. .	35.9	30.4		33.1	35.7
Average daily wet bulb.....°F. .	72.2	55.9		69.6	72.5
Average daily dry bulb.....do. .	80.6	76		81.3	87.2
Average daily relative humidity..percent..	68.2	59		56.4	49.8

1/ Pittsburgh readings taken at 8 a.m. and 8 p.m.

Generated on 2024-09-19 08:03 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

3. The total heat in the saturated air entering the mine at the desired temperature.

4. The efficiency of the air washer or cooler as a heat exchanger.

When air is passed through a single-tank air washer or cooler having three or more banks of sprays the relative humidity is raised to 100 percent, therefore, the wet-bulb, dry-bulb, and dew-point temperatures of the air leaving the cooler are equal. The temperature of the spray water also is raised to approximately the temperature of the air leaving the washer. However, with a double-tank cooler having four banks of sprays similar to those at mines A, B, and C and a counterflow recirculation of the cooling water, the temperature of the water leaving the cooler will be above that of the air leaving the cooler. According to manufacturers of equipment of this type, the temperature of the cooling water passing through a double-tank washer of proper design is raised approximately 1.4 times the difference between the temperature of the air leaving the cooler and that of the water entering the cooler.

After deciding on the temperature at which to hold the incoming mine air and estimating, with the aid of table 2, the maximum total heat in the air outside the mine the operator has some idea of the maximum amount of heat the cooling unit will have to remove. With this information, if the temperature of the available cold water is known, he can estimate the quantity of cold water required. For example, assume that in a mine in the Pittsburgh (Pa.) area, with the normal inside mine-air temperature 62° F., it is decided to hold the incoming mine air to 65° F. by passing it through an air washer or cooler. From figure 6 the total heat above 0° F. in 1 pound of dry air plus water vapor necessary to saturate it at 65° F. is 29.6 B.t.u. The maximum total heat (see table 2) in 1 pound of dry air plus moisture at noon in Pittsburgh for certain summer months is 40.1 B.t.u. The maximum demand on the cooling unit therefore will be the removal of 40.1 B.t.u. minus 29.6 B.t.u., or 10.5 B.t.u., per pound of dry air (plus vapor to saturate it) entering the mine. The volume (table 1, column 3) of 1 pound of dry air plus vapor to saturate it is 13.5 cubic feet at 65° F. Therefore, the maximum total heat to be removed from the air entering the mine per thousand cubic feet is $\frac{1,000}{13.5} \times 10.5 = 778$ B.t.u.

Assume further that the available cooling water has a temperature of 56° F. and that a double-tank cooler is installed with counterflow recirculation of cooling water. If the factor 1.4 is used the cooling water will have its temperature raised 65° F. (outgoing air temperature) minus 56° F. (incoming water temperature) times 1.4, or 12.6° F. Therefore 12.6 B.t.u. would be extracted for each pound of cooling water passed through the cooling unit, and the quantity of water required would be $\frac{778 \text{ B.t.u.}}{12.6 \times 8.3} = 7.4$ gallons per thousand cubic feet of air.

Generated on 2024-09-19 07:59 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

From these data the following formula may be deduced for determining approximately the gallons of cooling water required per thousand cubic feet of air entering the mine:

$$\frac{H - H' \times 1{,}000}{V \times 8.3 \times (t - t') \times E} = G,$$

where H = total heat per pound of outside dry air plus vapor content,

H' = total heat per pound of dry air plus vapor to saturate at incoming mine-air temperature,

V = volume of 1 pound of dry air plus vapor to saturate at incoming mine-air temperature,

8.3 = weight of 1 gallon of water,

t = temperature of air leaving cooling unit and entering mine,

t' = temperature of water entering cooling unit, and

E = factor of efficiency of unit as a heat exchanger.

From table 2 it will be noted also that the average daily wet-bulb and dry-bulb temperatures in Pittsburgh at noon are 65.2° and 77° F., respectively; therefore, the average wet-bulb temperature is only 0.2° higher than the desired incoming mine-air temperature.

When air is passed through an air washer or spray cooling unit, in which the relative humidity is raised to 100 percent, the temperature of the air is reduced to the wet-bulb temperature of the incoming air by evaporation only, therefore the water requirements at noon would amount to little more than the quantity necessary to compensate the loss by evaporation.

With the same incoming mine-air temperature of 65° F. and a cold-water temperature of 56° F., at Birmingham, Ala., during July and August, the maximum water requirement at noon would be 9.7 gallons per thousand cubic feet of air entering the mine. The requirement for the average of the monthly maximum would be 7.9 gallons, while the average daily requirement at noon would be 5.5 gallons.

At Evansville, Ind., the maximum requirement would be 10.2 gallons. The requirement for the average of the monthly maximums would be 8.6 gallons, while the average daily requirement at noon would be 3.3 gallons.

At Springfield, Ill., the maximum requirement at noon and the requirement for the average of the monthly maximums would be 9.6 gallons and 7.9 gallons, respectively, the same as at Birmingham, Ala. The daily average requirement at noon would be 2.9 gallons, which is considerably less than at Birmingham.

Generated on 2024-09-19 08:02 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

At Oklahoma City, Okla., the maximum requirement at noon would be 8.8 gallons. The requirement for the average of the monthly maximums would be 7.3 gallons, while the average daily requirement at noon would be 4.7 gallons.

Surface cooling coils of the fin type, with which there is a counterflow of water and air, might be used in place of the spray-type cooler. Doubtless such a cooler would use much less water because of the more perfect counterflow of air and water and the greater exchange of heat between the air and water. The disadvantages of a cooling unit of this type, however, are that it is more costly to install and offers much more resistance to the flow of air than a spray cooler without moisture eliminators.

An air-cooling unit will be most effective at a new mine where the temperature and moisture content of the mine air vary at the working faces. In fact, it is questionable whether there would be any advantage in cooling the air entering a mine in which the workings are so far advanced that the mine air has assumed the same temperature as the strata before reaching the active workings. In a mine with extensive workings the air courses and entries undoubtedly have been timbered enough to prevent roof falls that might result from changes in the temperature and moisture content of the air entering the mine.

Heating Mine Air During Winter

An air washer that is used to cool the air in the summer could be used also to heat the incoming mine air during the cold months by heating the water in the recirculating spray tank or by admitting steam to the air current just outby the recirculating sprays. By the use of cooling water in the summer and steam in the winter the air entering the mine could be held at a nearly uniform temperature throughout the year.

Probably the principal advantage of warming and moistening the mine air in winter would be to prevent the drying out of the mine with the accompanying increased coal-dust explosion hazard. It might be found, however, that maintaining the air entering the mine at uniform temperature throughout the year would have a beneficial effect on the roof, particularly in a new mine where the air temperature at the face workings are likely to vary considerably at different times in the year.

In several mines attempts have been made to warm and moisten the air by turning exhaust steam into the intake air course. This method has the decided disadvantage of creating a fog that would not be permissible on a haulage road. In addition temperature control over the admission of steam was not attempted, and as a result both the temperature of the air and its moisture content varied widely. However, if the steam, either exhaust or live, or both, is used in conjunction with an air washer and the admission of steam is regulated by temperature controls, the fog could be eliminated and the moisture content could be maintained near the saturation point.

Generated on 2024-09-19 08:01 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY

Frequently the question has been asked of how much steam would be required to warm mine air in the winter. Of course, the quantity of steam required per thousand cubic feet of air will vary with the number of degrees it is expected to raise the temperature of the air and the moisture content of the air to be heated.

Assuming that it is desired to maintain the incoming mine air at a minimum temperature of 55° F. and that the minimum outside temperature is 0° F., then the total heat (see table 1) above zero of 1 pound of dry air plus moisture necessary to saturate it at 55° F. is 23.04 B.t.u., and the volume of 1 pound of dry air plus moisture to saturate it at this temperature is 13.16 cubic feet. Therefore it would require $\frac{23.04 \text{ B.t.u.} \times 1{,}000}{13.16 \text{ cubic feet}} = 1{,}751$ B.t.u. to raise the temperature of 1,000 cubic feet of air from 0° to 55° F. and to saturate it.

Assuming that the total heat of 1 pound of steam that is available for raising the temperature of the air is 1,000 B.t.u., it would require 1,751 ÷ 1,000 = 1.75 pounds of steam per thousand cubic feet of air.

Under the old method of rating boilers this would require approximately 3 boiler horsepower per thousand cubic feet of air per minute or, if exhaust steam is used, the exhaust from about 3.5 engine horsepower per thousand cubic feet per minute, assuming 30 pounds of steam per horsepower-hour.

As only about 7 percent of the heat of steam above 32° F. appears as work in the average noncondensing engine, naturally it would be much more economical to utilize the steam for the generation of power and heat the air with the exhaust rather than to use live steam for this purpose. The average temperature in winter throughout the coal fields is above 30° F., therefore the average quantity of steam necessary to warm the air entering the mine would be only about one-half the above amount.

Generated on 2024-09-19 08:03 GMT / https://hdl.handle.net/2027/osu.32435030643977
Public Domain, Google-digitized / http://www.hathitrust.org/access_use#pd-google
Digitized by Google
Original from THE OHIO STATE UNIVERSITY